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Article

Science Teachers' Perceptions and Self-Efficacy Beliefs Related to Integrated Science Education

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Abstract: To understand how integrated science education (ISE) can be transferred into successful classroom practices, it is important to understand teachers' perceptions and self-efficacy. The focus of this study is twofold: (1) to understand how teachers perceive ISE and (2) to assess if science teachers' perceptions of and experiences with integrated education correlate with their views on self-efficacy in relation to ISE. Ninety-five Finnish science teachers participated in an online survey study. A mixed method approach via exploratory factor analysis and data-driven content analysis was used. Self-efficacy emerged as a key factor explaining teachers' perceptions of and their lack of confidence in implementing ISE as well as their need for support. In addition, teachers regarded ISE as a relevant teaching method, but challenging to implement, and teachers primarily applied integrated approaches irregularly and seldom. Furthermore, teachers' experiences with integrated activities and collaboration correlated with their views on integrated education and self-efficacy. These findings indicate teachers need support to better understand and implement ISE.

Keywords: integrated science education; interdisciplinary education; self-efficacy; teachers' perceptions; teacher training

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1. Introduction

Science teachers have a pivotal role in integrating new research and science education reforms into classroom practices. Their beliefs and perceptions about integrated science education (ISE) should be considered as the change agent in such situations [1–6]. ISE is an effort to integrate science curriculum contents into a meaningful whole by a constructive and context-based approach that crosses subject boundaries and links learning to the real world [7,8]. It is a current issue of focus among researchers due to the many promises it offers, such as giving pupils a more coherent understanding of complex everyday life phenomena, increasing conceptual understanding, developing students' 21st-century skills (e.g., critical thinking and problem-solving skills) and increasing students' interest in school and science subjects [7,9–14]. Due to the possibilities, recent policy reforms [15,16] across the globe tend to emphasise the need for more integrated approaches to science education [7,17].

Implementing more integrated approaches to science education, especially approaches that push beyond traditional science subjects, presents teachers with multiple barriers to overcome. The challenges include, for example, pedagogical, curriculum and structural challenges; concerns about students and assessment; a lack of teacher support [5,18,19]; as well as challenges related to the broad range of ways of defining and implementing integration [7,20–22], for example as Science, Technology, Engineering and Mathematics (STEM) education [17] or Science, Technology, Society, and Environment (STSE) education [23].

In a scenario involving challenging educational reforms, teachers' self-efficacy and their perceptions are likely to become important aspects of everyday science teaching practice [24,25], which can potentially explain some of the phenomena observed in science education associated with teachers' resistance to reforms [26,27]. One resulting problem is providing teachers with a new curriculum without addressing the underlying educational belief systems, which are dependent on various factors, including prior experiences as well as self-efficacy, and which can lead to little meaningful change [27–29].

Tschannen-Moran and Hoy [25] have defined teachers' self-efficacy as a future-oriented belief about the level of competence a person expects he/she will display in a given educational situation. Such beliefs influence the courses of action teachers choose to take, their level of effort, their perseverance in the face of obstacles and what they ultimately accomplish [30]. As self-efficacy beliefs are context-related and dependent on perceptions of the desired outcomes [30], it follows that teachers' perceptions of ISE and their experience with implementing an integration approach influence their self-efficacy belief in ISE. However, science teachers' perceptions regarding integration and the need for integration vary [5,31,32], and research evidence on science teachers' self-efficacy for ISE is not comprehensive.

This mixed method research project began with a focus on science teachers' perceptions of ISE, but the strong emphasis on self-efficacy encouraged researchers to explore it as a research question in its own right, one with links to teachers' experiences and perceptions of ISE. Three research questions were asked:

- How do science teachers perceive ISE?
- How do science teachers perceive their self-efficacy in relation to ISE?
- Do science teachers' self-efficacy beliefs about ISE correlate with their experiences with and perceptions of ISE?

The data for this survey were collected at a time when integrated education policies were first being introduced to Finnish educational systems, thus it offers insights on a situation of lower self-efficacy related to challenging curriculum reforms for both primary and secondary school science teachers.

1.1. Integrated Science Education in Finnish Education System

For the first time, the national curriculum in Finland dictates primary and lower secondary schools to organise yearly a multidisciplinary learning module. The schools are obligated to plan and implement these 'tools for integrating learning and for increasing the dialogue between different subjects' in cooperation between different subjects and to involve pupils in their planning [15]. Furthermore, integrated elements are impeded in the learning goals of individual subjects.

The Finnish curriculum offers a broad definition of integrated education that emphasises, among other things, the development of the whole person (social, affective, cognitive), the integrity of subject matter knowledge and the use of interdisciplinary teaching [15]. It is closely linked to context-based education [33], as it aims to link subject matter with relevant contexts from students' everyday lives and society. Furthermore, the curriculum has similar principles guiding it as the framework for K-12 science education [16], but with one distinction: in Finland, instead of cross-cutting concepts, the emphasis is on crosscutting skills, called transversal competencies, which can be achieved through integrated education.

The science curriculum is organised and taught as separate subjects in Finland from lower secondary school (7th grade) onwards. The National Core Curriculum provides a common direction and objectives for school education, but teachers have pedagogical autonomy. They can decide themselves the methods of teaching as well as textbooks and materials [34]. Due to the pedagogical autonomy of Finnish teachers, their perceptions of ISE can have a considerable effect on the integrated practices.

2. Theoretical Background

The main aspects of integrated education are drawn from Dewey's [35,36] concepts of school as a society in miniature, where learning is student-centred and based on real life and authentic activities and the aim is to teach skills and provide knowledge relevant to the learners as individuals and members of society. However, the current discourse on integrated education is a contested one, with various typologies and terms that are sometimes used interchangeably [7,14,22,37].

The forms of integration can be defined by the degree of transfer or connection being made between contents or disciplines. Transfer of learning can be described as the ability to apply what one has learned in one situation to a different situation [38,39]; therefore, it can be seen as the main goal of integrated education, which aspires to teach the skills and knowledge needed in real life. Four terms widely used to describe integrated approaches, ranging from least to greatest level of integration, include integration within the subject, multidisciplinary approaches, interdisciplinary approaches and transdisciplinary approaches.

- Integration *within the subject* focuses on the integrity of subject matter knowledge [40].
- *Multidisciplinary* approaches juxtapose disciplines, adding information and methods from other disciplines [21,22], while still retaining the elements of each discipline and thereby keeping them somewhat separate. Choi and Pak [41] define multidisciplinary teaching as drawing on knowledge from different disciplines while still maintaining the boundaries between them. A similar concept is correlated curricula [20] and Hurley's [40] notion of sequenced and parallel integration.
- *Interdisciplinary* approaches go further and are characterised by interacting with, blending and linking different disciplines [21,22]. Lederman and Niess [42] define interdisciplinary education as a blending of different subjects by making connections between them, but still retaining the subjects as identifiable entities. Choi and Pak [41] push the idea of transfer further by stating that interdisciplinarity analyses, syntheses and harmonises the links between disciplines into a coordinated and coherent whole. Related terms used by different authors include Dillon's [43] pedagogy of connections [43], shared curricula by Applebee et al. [20] and Hurley's [40] partial and enhanced integration [40].
- The greatest degree of integrative restructuring is associated with *transdisciplinary* approaches [21], which integrate the natural, social and health sciences in a humanities context and allow them to transcend their traditional boundaries [41]. This can go as far as breaking down traditional disciplinary boundaries and reconstructing curricula based on cross-cutting concepts. The central idea is also included in the terms reconstructed curricula by Applebee et al. [20] or Beane's [8] curriculum integration.

Science integration has traditionally meant integration having to do with mathematics, engineering and/or technology, such as STS (science–technology–society) or STEM (science–technology–engineering–mathematics) education [7,9]. During the past decade, increasing interest has been shown in taking a broader approach to science integration, for example, a move to STEAM education by including art in STEM [14,17]. Indeed, some evidence supports the inclusion of artistic processes in science as they can promote students' conceptual understanding, attitude towards science, involvement in science learning [12] and enable a more realistic transdisciplinary learning experience [44]. However, an agreed understanding about the nature and definition of STEM does not exist [17,45], evidence on learning outcomes in STEAM education are lacking [46], and science teachers struggle with the use of these integrative methods [18,32,45].

2.1. Teachers' Perceptions and Beliefs about ISE

Research findings indicate a strong relationship between teachers' educational beliefs, perceptions and teaching practices [28,29]. For example, teachers' attitude towards reforms or their beliefs about the necessity of reforms is amongst the strongest predictors of the extent to which such reforms would be implemented in the classroom [27,45,47]. However, even when a teacher holds a constructivist and inquiry-driven belief in science teaching, oftentimes those beliefs do not translate into correlated practices [28]. Pajares [29] described teachers' educational belief system as composed of various educational beliefs connected to one another, and it is according to these connections that beliefs are prioritized and have context-specific effects. Therefore, having conflicting educational beliefs, such as subject matter beliefs and self-efficacy, can constrain teachers from implementing even positively valued reforms [28,48]. In this study, we focus on the connection between teachers' experiences of ISE, their perceptions of implementing ISE and their self-efficacy beliefs in relation to ISE.

Teachers' Perceptions of Implementing ISE

Teachers seem to value ISE [5,7]; however, their perceptions on the effectiveness of integrated approaches are mixed [7]. Studies have determined several barriers reported by teachers implementing integrated approaches to science education [5,18,19,24,31,49]. For example, evidence suggests that teachers who perceive more time constraints use fewer inquiry-based strategies [7,49], whereas, contrastingly, teachers who perceive less pressure at work are more likely to implement student-centred approaches [50]. The challenges to integration include scheduling restraints, which make it difficult for teachers to work together or integrate their teaching [5,19]. Furthermore, asking teachers to teach another subject may create new knowledge gaps and challenges for teachers, exposing holes in their own understanding of subject matter knowledge, pedagogical knowledge and interdisciplinary issues [19]. According to Margot and Kettler [5], teachers' prior experiences with integration affect their perceptions and willingness to implement ISE. Therefore, challenging experiences with ISE may hinder teachers from implementing it in the future.

2.2. Teachers' Self-Efficacy in Relation to ISE

Bandura [30] defines perceived self-efficacy as belief in one's capabilities to organise and execute the courses of action required to produce certain educational attainments [30]. Science teachers' self-efficacy beliefs affect their general orientation toward science education as well as their behaviour in the classroom [25,29,30]. Teachers with higher perceptions of self-efficacy are more likely to perceive challenges associated with a specific teaching task, such as ISE, as surmountable, and therefore, they remain more committed to continue executing the task [25,30]. High-efficacy science teachers include students' problem-solving and logical thinking skills in a real-life context, they depend less on curriculum guidelines, they use themes to integrate science into other subjects and they emphasise hands-on science experiences [51]. Teachers with lower efficacy favour a custodial orientation that takes a pessimistic view of student motivation, emphasises control of classroom behaviour through strict regulations and relies on extrinsic inducements and negative sanctions to motivate students to study [30,51].

Teachers' self-efficacy is a context-specific judgment [30]. Therefore, science teachers' self-efficacy beliefs can vary from one integrated teaching situation to another. More research is needed to better understand teachers' self-efficacy for ISE. Bandura [30] identified mastery experiences as one of the main sources of self-efficacy, along with vicarious experiences, verbal persuasion and emotional and physiological states. Most teachers have little experience with integrated approaches to science education, especially beyond science subjects [7,31]. Furthermore, teachers have reported a lack of vicarious experiences as well as support from school and colleagues [5,19,31].

3. Methodology

Both qualitative and quantitative methods were used in this study to better understand science teachers' perceptions of ISE and of self-efficacy in relation to ISE (see Figure 1). The research was data-driven and started with mapping out common denominators for science teachers' perceptions via Exploratory Factor Analysis (EFA). The identified factor solution was used as a thematic aid when conducting content analysis of the open-ended questions about how best to define IE and the possibilities and challenges of implementing ISE. Researchers also gathered together the quantitative descriptive data about the science teachers and their experiences with ISE.

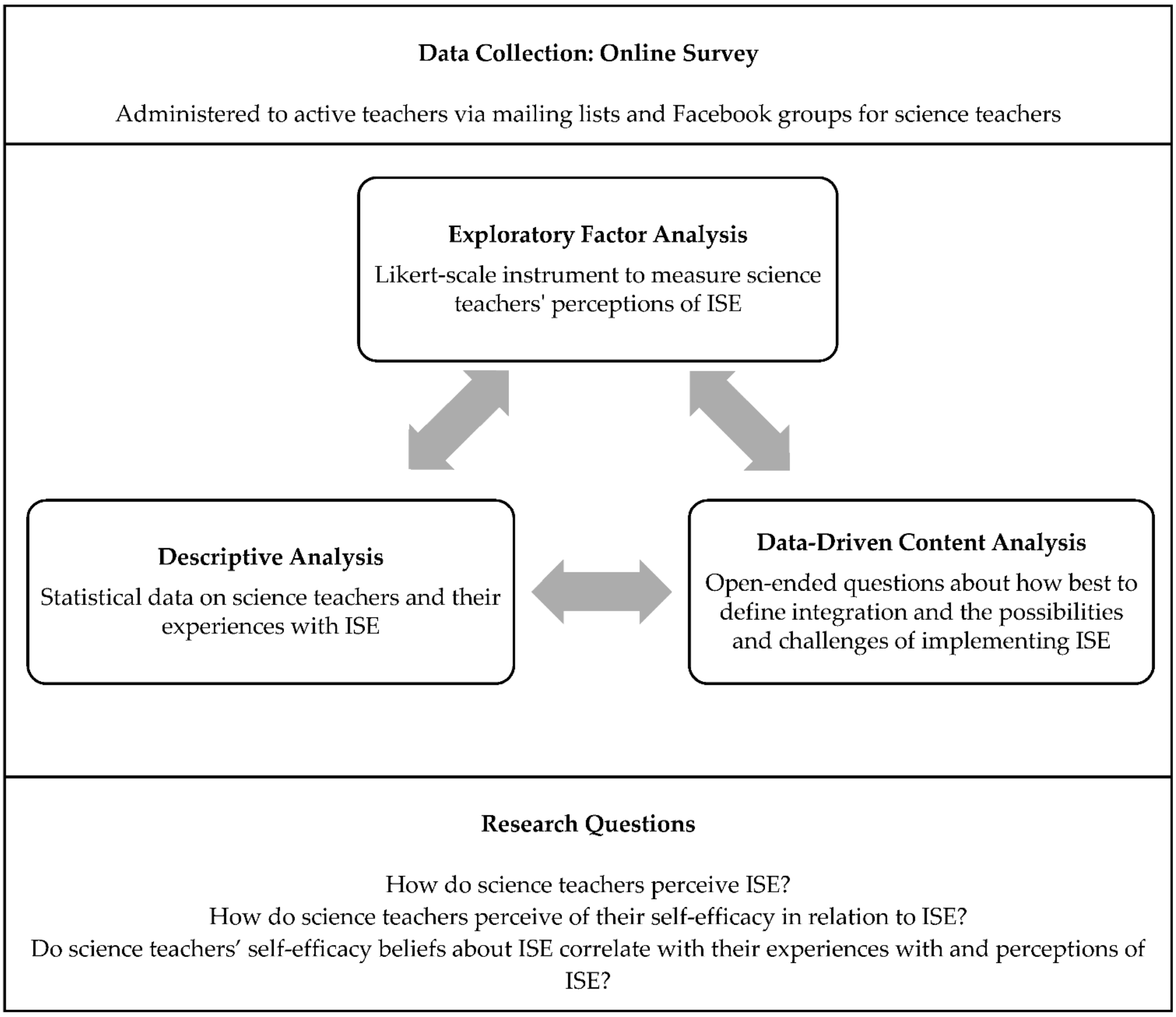

Figure 1. Mixed method research approach was used in this study.

3.1. Survey Instrument

As described in Figure 1, survey was used as a data collection method. An online survey was administered to Finnish teachers via mailing lists and Facebook groups for science teachers on the eve of a curriculum change (see Section 1.1), in November 2015. The questionnaire was constructed with quantitative and qualitative questions to measure teachers' perceptions of integrated education and the implementation of ISE as well as their teaching experiences with it. Measures included background structured questions, open-ended questions and a five-point Likert-scale instrument with 31 ISE-related items measuring degree of agreement, ranging from five 'strongly agree' to one 'strongly disagree' and an additional 'I don't know' option. The instrument items were formulated based on earlier research on ISE [7,24,40,47]. Two fellow science education researchers examined the face validity of the survey. A pilot test followed by discussions with a few pre-service teacher students was conducted, resulting in minor changes to the survey.

3.2. Participants

Ninety-five Finnish science teachers took part in the survey. Excluding seven mathematics teachers, all respondents taught one or two science disciplines (physics, chemistry, biology or geography). The disciplines were often coupled with teaching mathematics. A comparison of the number of teachers in basic and general upper secondary education in Finland in 2016 and in the survey (94.7% of the respondents) are presented in Table 1.

This study does not represent the teachers in vocational or liberal education as only a few respondents identified themselves as teachers in vocational or liberal education.

Table 1. Number of science and mathematics teachers in basic and general upper secondary education in Finland and in the survey (respondents). Numbers shown per primary taught subject.

	Number of Teachers in Finland [1]	Respondents	Respondents (% of Teachers)
Basic education [2]			
Mathematics or data science	1677	32	1.91
Science [3]	1310	25	1.91
Other	23,659	11 [4]	0.05
Total	26,646	68	0.26
General upper secondary education			
Mathematics or data science	760	10	1.32
Science [3]	678	12	1.77
Other	3779	0	0.00
Total	5217	22 [5]	0.42

[1] Source: Vipunen–Education Statistics Finland (https://vipunen.fi/en-gb/, accessed on 25 November 2020). Personnel, statistical year 2016, survey response rate 66%. [2] Includes teachers in primary and/or lower secondary schools. [3] Science subjects included biology, physics, chemistry, geography, and environment and nature studies. [4] All respondents were classroom teachers providing primary education. [5] Eight teachers providing both lower and upper secondary education are reported in the number of upper secondary education teachers.

More than 75% of the science teachers had over ten years of teaching experience. However, their experience with integrated practices and collegial collaboration was limited (see Table A1 in Appendix A). The results show that primary school teachers have used all of the integrated practises more than secondary school teachers. Four secondary school teachers, three with over ten years of experience and a novice teacher, reported that they had never implemented any form of integrated practices.

Most teachers (93.5%) had organised integrated activities, such as a theme day, class event or a school visit, at least once a year. The six teachers who had never organised any integrated activities were all from secondary schools. Half of the teachers had never executed more extensive (at least a week in length) integrated study units, while 28.7% reported having done so less than five times during their teaching career. Collaboration within the same subject was more common than interdisciplinary collaboration. However, 11.3% of the teachers stated that they had never collaborated with colleagues.

The sample does not represent the science teacher population because of the channels used for distributing the e-survey. Therefore, the results might overtly present the opinions of teachers who are actively following online forums for science teachers and who are interested in developing their education, thus creating a possible bias in the sample.

3.3. Mixed Methods

The mixed method approach via exploratory factor analysis, data-driven content analysis and descriptive analysis was used in this study to better understand science teachers' perceptions of ISE and of self-efficacy in relation to ISE (see Figure 1).

3.3.1. Exploratory Factor Analysis

EFA was conducted using SPSS (Software Package for Social Science, version 24.0). The survey consisted of 31 five-point Likert scale variables that tested teachers' conceptions of ISE. Three variables with 20% or more missing values were removed from the initial factor analysis, resulting in 28 items and a N:p ratio of 3:1. As this is a small dataset for factor analysis, the researchers felt that omitting cases with missing values would cause more bias than using a missing value technique that retained all participants. Therefore, only cases with more than 40% missing values were eliminated to maximise the sample size ($n = 89$). Further, the factor extraction process to diminish biased results was meticulously implemented according to the recommendation given by McNeish [52] in his study on the combined effect of a small sample and missing values when using EFA, while also ensuring that the extracted factors make conceptual and theoretical sense [53].

Missing values (3.4%) were tested using Little's MCAR test, and they proved to be missing at random (MAR) (Chi-Square = 716.571, DF = 653, Sig. = 0.042). Both predictive mean matching (PMM) and expectation maximisation (EM), the recommended missing value techniques [52,54], were tested with similar results. EM was chosen for its simplicity for making calculations in SPSS. Multicollinearity was checked and did not cause issues when conducting EFA. Likewise, multivariate outliers were checked, with none being found.

The factorability of the 28 variables was examined using several criteria that supported the usefulness of factor analysis for the data and the inclusion of all the items in the analysis. First, the Kaiser–Meyer–Olkin measure of sampling adequacy proved adequate (KMO = 0.672), while Bartlett's test of sphericity was significant ($p < 0.001$). Second, all the diagonals of the anti-image correlation matrix were above 0.5, except for four variables (>0.4). Finally, the initial communalities were all above 0.4. Principal axis factoring (PAF) was used as an extraction method with promax as a rotation method.

Several extraction criteria were employed to determine the best number of factors, including Kaiser's rule (eigenvalue > 1), scree plot and parallel analysis [55] with permutation. Seven variables were omitted during several factor runs because they failed to meet the minimum criteria of having (1) a primary factor loading of 0.4 or above and (2) a cross loading of 0.3 or above. For the resulting 21 variables, a factor structure with four factors was clearest and best described the data according to the researchers.

3.3.2. Content Analysis

The analysis here included science teachers' answers to open-ended questions about how best to define integration and the possibilities and challenges of implementing ISE. The researchers discarded answers and text segments that were irrelevant to the principal focus of this content analysis. The technique employed here utilises frequency counts as well as more interpretive, data-driven thematic analysis that focuses on describing the meaning of communications in specific contexts [56,57]. Using both quantitative and qualitative analysis of texts adds to the quality of the analysis [58].

Content analyses should be systematic and replicable [56,59]. However, qualitative content analyses require greater researcher judgments in coding and in data analysis [56]. With qualitative content analysis, the inter-coder reliability is of particular significance, since content-related arguments should be given preference over procedural arguments and validity should be regarded more highly than reliability [57].

The preliminary coding and category formulation process, based on the four-factor EFA solution, was carried out with a portion of the sample (secondary teachers, approx. 2/3 of the total sample) by two researchers. The similarities and differences were discussed before one of the researchers formulated a coherent category system that was tested via inter-coder reliability. The category system included three parts, one for each question. The coding and review process was repeated by the researcher and each time after a discussion with the coder until a satisfactory kappa result (0.7 or higher) was obtained. For the final category solutions, inter-coder testing was conducted both with an outside coder (Cohen's kappa 0.804) and with the two researchers who had formulated the preliminary categories (Cohen's kappa 0.914).

4. Results

The findings on science teachers' perceptions and self-efficacy in the context of ISE are presented per research focus. First, we present teachers' perceptions of ISE (see Section 4.1). Second, we show results on teachers' self-efficacy (see Section 4.2) that proved to be a key factor in the exploratory factor analysis explaining most (23.04%) of the total variance in teachers' perceptions of ISE. However, as the findings are mainly based on the categories (content analysis) and factors (exploratory factor analysis), we shortly present these solutions before delving deeper into the results.

The final factor solution included variables with factor loadings over 0.4 and explained 52.5% of the total variance in teachers' perceptions of ISE via the following four factors: (F1) *self-efficacy for ISE*, (F2) *relevance of ISE*, (F3) *challenges of ISE* and (F4) *multifaceted nature of ISE*. Table A2 (see Appendix A) shows the factor loading matrix and communalities for all variables in the final four-factor solution. We examined the internal consistency of each factor using Cronbach's alpha, and the results were moderate: (F1) *the self-efficacy for ISE* factor (7 items) was 0.874, (F2) *the relevance of ISE* factor (5 items) was 0.858, (F3) *the challenges of ISE* factor (4 items) was 0.765 and (F4) *the multifaceted nature of ISE* factor (5 items) was 0.688. No increases in alpha for any of the factors would have been achieved by eliminating more items.

The category system resulting from the content analysis consisted of three parts:

1. Categories of integrated education included eight categories (see Section 4.1.1) with *interdisciplinary*, *wholeness* and *phenomenon-based* being the most frequent concepts teachers used to describe integrated education.
2. The possibilities of ISE included eight categories (see Section 4.1.2). *Integrity of knowledge* and *motivation* were the two categories best describing teachers' perceptions of the possibilities.
3. The challenges of ISE included seven categories (see Section 4.1.3) with *administration* and *time* related challenges being the main barriers for teachers for implementing ISE.

4.1. Teachers' Perceptions of Integrated Science Education

Teachers' perceptions of ISE and the possibilities and challenges of implementing ISE are described in three sections named according to the corresponding factor: 4.1.1 Multifaceted nature of ISE, 4.1.2 Relevance of ISE and 4.1.3 Challenges of ISE.

4.1.1. Multifaceted Nature of ISE

Factor F4, *the multifaceted nature of ISE*, consisted of five items, which explained 5.06% of the total variance with factor loadings ranging from 0.45 to 0.68 (see Table A2 in Appendix A). One variable (in integrated education, one must apply the skills and knowledge learned within the context of everyday life), with a primary loading 0.55, had a cross-loading of 0.30 for the challenge factor. However, the researchers felt the variable fits into the context of the factor and the solution was stronger with this variable than without it.

Content analysis of the way science teachers choose to define integrated education further elucidated the diverse nature of ISE (see Table 2). The variable stating integrated education as student-centred approach characterised factor F4 the most; in contrast, this characterisation did not appear equally in teachers' definitions of integrated education in the content analysis. For the most part, teachers' definitions emphasised (1) collaboration between subjects, which we categorised either as *multidisciplinary* or *interdisciplinary*, and (2) the importance of examining the complexity of issues as comprehensive whole (*wholeness*) and using a *phenomenon-based approach*. Some teachers presented contradictory views as to whether such integration should take the form of subject-based or phenomenon-based integration.

Teachers' experiences with integrated activities affected their perception of ISE. Teachers who reported regularly engaging in integrated activities (at least five times a year) agreed more with statements about the multifaceted nature of ISE ($p = 0.031$, Fisher's Exact Test). Furthermore, we noted some interesting differences between the views of primary and secondary school science teachers. First, their perception of ISE as being interdisciplinary varies: 30.6% for primary school teachers and 15.7% for secondary school teachers. Second, compared to primary school teachers, the perceptions of secondary school teachers aligned more with subject-based integration (12.9% of secondary school teachers; 2.8% of primary school teachers) and multidisciplinary approaches (11.4% of secondary school teachers; 5.6% of primary school teachers). We investigated these differences using cross tabulation but did not find enough evidence to suggest a statistically significant association since the *p*-value was greater than 0.05 ($p = 0.198$, Fisher's Exact Test).

Table 2. Factor F4 (multifaceted nature of integration) variables with corresponding categories of content analysis regarding science teachers' definitions of integrated education (IE). Frequencies (%) are shown based on occurrences ($n = 127$) per category.

Factor F4 Variables (Factor Loading)	Examples of Science Teachers' Definitions of Integrated Education (IE)	Categories of IE	Freq (%)
Student-centred approach is essential in IE (0.68)	'Teaching disciplines through students' lives and their experiences.' (Teacher 39) 'Personally meaningful for the students.' (Teacher 59) 'Help and support the students according to their individual needs.' (Teacher 74)	Student-centred	7.1
IE should be linked to students' daily lives and to society (0.57) In IE, one must apply the skills and knowledge learned within the context of everyday life (0.55)	'The understanding of the wholeness of issues influencing peoples' living environment.' (Teacher 44) 'Integrated education combines the school world and daily lives together, in which case the learning will be done from the perspective of multiple disciplines, students' daily lives and even working life.' (Teacher 32)	Everyday life	7.1
IE requires collaboration between subjects (0.46)	'Discussing phenomenon-based issues that cross subject boundaries. The aim is to understand the links and dependencies between different contents of learning.' (Teacher 18) 'Integrated education refers to crossing subject boundaries and teaching doesn't necessarily happen in school.' (Teacher 32)	Interdisciplinary	21.3
	'Learning about health education, home economics, biology and environmental issues in chemistry. Traffic, physical education, etc., together with physics. Math can be applied within all in appropriate places.' (Teacher 82) 'In practice, this means that in mathematics teaching, one can use examples from other subjects and in other subjects use mathematics.' (Teacher 97) 'Learning about a common topic in both subjects, discarding overlapping matter.' (Teacher 2)	Multidisciplinary	7.9
In IE, it is essential to examine the complexity of a phenomenon comprehensively (0.45)	'Teaching forms a logical whole, in which facts link to each other either within traditional subjects or between them. The learning content forms an integrated [whole].' (Teacher 90) 'Students form an integral understanding of concepts and contents.' (Teacher 52)	Wholeness	21.3
	'An interesting issue defines the direction of teaching and the skills to be learned.' (Teacher 54) 'Phenomenon-based education, where matters of several subjects are learned at the same time.' (Teacher 85)	Phenomenon-based	16.5
	'A student can link knowledge and skills across disciplines and within discipline. . . . Math, physics and chemistry are a difficult combination, as people begin to have their thumbs in their palms. You need to know the basics of the subjects and then you can start to innovate...' (Teacher 31) 'It is rehearsal of previously learned [subject matter], adding, deepening and applying it.' (Teacher 100)	Subject-based	10.2
		Other	4.7
		Total	100

In conclusion, teachers in the study defined the *multifaceted nature of ISE* mostly as a student-centred approach that requires collaboration and links different subjects with students' daily lives by focusing on a specific phenomenon or the broader context of daily life and applying skills and knowledge learned in school in such a context. Furthermore, a clear positive correlation (0.44) existed between this factor and the *relevance of ISE* factor.

4.1.2. Relevance of ISE

Factor 2, *the relevance of ISE*, explained 16.43% of the total variance and included five variables underlining different dimensions of relevance, with factor loadings ranging from 0.61 to 0.86 (see Table A2 in Appendix A). Based on the factor variables, the science teachers reported that ISE is *personally relevant* (I would like to use more integrated approaches in my teaching, 0.86), *vocationally relevant* (I think integrated education is a suitable method to teach the subjects I am teaching, 0.69) and *socially relevant* (integrated education helps students to understand the interconnected nature of issues better than traditional education, 0.68).

Science teachers' perceptions of the possibilities of ISE offer some explanation as to why they view ISE as being relevant (see Table 3). The *learning outcomes* category is linked to all other categories, as learning is the general aim of all teaching. This was most evident with the category *integrity of knowledge*, which includes the ability to transfer knowledge and further illustrates how teachers perceive ISE as especially vocationally relevant.

Table 3. Factor F2 (relevance) variables with corresponding categories of content analysis regarding science teachers' perceptions of the possibilities of integrated science education (POSS). Frequencies (%) are shown based on occurrences (n = 100) per category. The abbreviation IE is used for integrated education in the table.

Factor F2 Variable (Factor Loading)	Examples of Science Teachers' Perceptions of POSS	Categories of POSS	Freq. (%)
I would like to use more integrated approaches in my teaching (0.86)	'All the pupils like this method of working. It is also inspiring for myself.' (Teacher 53) 'Motivation increases when one can apply what one has learned in new situations.' (Teacher 100).	Motivation	22.0
I think it is important to implement integration within my own teaching (0.82) I think IE is a suitable method to teach the subjects that I am teaching (0.69)	'The meaningfulness of learning increases.' (Teacher 19) 'Students can get a better understanding of the fact that chemistry is part of everyday life.' (Techer 98) '[Students] can apply things to their daily lives and studies.' (Teacher 5)	Meaningful	13.0
	'It adds a new perspective to one's teaching and one is also learning him/herself.' (Teacher 8) 'Special emphasis is on data acquisition and presentation. The use of ICT is easily incorporated into work.' (Teacher 88)	Variety	8.0
	'Increases well-being at school.' (Teacher 26) 'Students' personal growth in becoming independent.' (teacher 89) 'Joy of learning.' (Teacher 34)	Well-being	8.0
	'Only the sky is the limit . . . student-centred and inquiry-based learning can be better executed, room for students' interests and creativity.' (Teacher 81) 'Students learn from each other, which is a very good thing!' (Teacher 7)	Student-centred	4.0
IE helps students to understand the interconnected nature of issues better than traditional education (0.68)	'The overlapping content of different subjects can be utilised better. The fact that one has learned something in chemistry does not mean one could not study it again in physics. When students realise that they have already learned this in a different context, the "overload" decreases.' (Teacher 30) 'Issues and phenomena will form entities, and all will be linked together.' (Teacher 12)	Integrity of knowledge	27.0
With IE, one can achieve better learning outcomes than with traditional education (0.61)	'Team working skills develop for all involved.' (Teacher 38). 'One learns to pursue knowledge, edit tables and draw conclusions. One learns to apply mathematics.' (Teacher 82) 'One can get absorbed in one's topic more thoroughly.' (Teacher 68)	Learning Outcomes	13.0
		Other	5.0
		Total	100

For the most part, teachers described ISE as relevant because of its potential to (1) motivate teachers or students, (2) enable greater integrity or cohesion of learned knowledge, and (3) be meaningful. This was affirmed by teachers' perceptions of the most essential aims of integrated education for their own subject teaching (see Table 4). The three aims emphasised as the most essential for ISE related to the same sources of relevance, namely *integrity of knowledge*, *motivation* and *meaningfulness*.

Table 4. The frequencies of science teachers' views on the essential aims of integrated science education (ISE). Teachers were asked to choose a maximum of three aims. Frequencies shown per occurrence and per teacher (n = 95).

Aims Associated with ISE	Freq	Freq (% of Occurrences)	Freq (% of Teachers)
Understanding the nature of science and 'how science is done'	19	7.42	20.00
Teaching the subject contents as integrated modules	49	19.14	51.58
Student's growth as an individual	27	10.55	28.42
Learning skills and knowledge needed for everyday life	46	17.97	48.42
Learning skills and knowledge needed from the societal perspective	38	14.84	40.00
Mastery of the subject content (including skills and knowledge)	26	10.16	27.37
To motivate students to study mathematics and science	49	19.14	51.58
Other (specified as collaboration)	2	0.78	2.11
Total	256	100.00	269.47

The 26 teachers who reportedly view mastery of the subject content as an essential aim of ISE were an anomaly among the teachers in the study, as they perceived ISE as being less relevant (p = 0.040, Fisher's Exact Test) and a method not well suited to their teaching objectives (p = 0.031, Fisher's Exact Test). They also reported being less willing to incorporate integration into their teaching (p = 0.034, Fisher's Exact Test). This group of teachers did not differ from the other teachers by school level or by their years of experience in teaching or applying integrated methods.

Furthermore, cross tabulation revealed a statistically significant difference between teachers at different school levels in regard to their views on the relevance of ISE (p = 0.010, Fisher's Exact Test). Secondary school teachers, whether at lower, combined or upper secondary schools, to some extent expressed disagreement with the notion that ISE is relevant, whereas none of the primary school teachers disagreed with it. However, lower secondary school teachers tended to be more closely aligned with primary school teachers, with more than 85% of teachers in both groups with agreeing or strongly agreeing with the relevance statements.

4.1.3. Challenges of ISE

The factor analysis identified *the challenges of ISE* as a latent factor (F3) comprised of four items that explained 7.94% of the variance, with factor loadings ranging from 0.46 to 0.86 (see Table A2 in Appendix A). The variables explaining the challenge factor for the most part emphasise ISE as a time-consuming and laborious method. This factor had a negative correlation with the relevance factor (see Table A3 in Appendix A), indicating that teachers who view integrated approaches as more relevant tend to regard ISE as less of a challenge. The content analysis revealed a wider range of challenges for ISE. The similar range of challenges identified by the teachers, especially those related to time and administration, further highlighted issues related to the factor variables (see Table 5). No teachers provided clarifying statements for the variable '*Implementing integrated education requires cutting subject matter from the lessons*' (0.50), thus we omitted it from the table.

Table 5. Factor F3 (challenges) and F1 (teachers' self-efficacy) variables with corresponding categories of content analysis regarding science teachers' perceptions of the challenges of integrated science education (CHAL). Frequencies (%) are shown based on occurrences (n = 124) per category.

Factor Variable (Factor Loading)	**Examples of Science Teachers' Perceptions of CHAL**	**Categories of CHAL**	**Freq. (%)**
F3: Implementing integrated education is more laborious than traditional education (0.85)	'The laboriousness of planning [integrated lessons].' (Teacher 67) 'Finding suitable topics that offer enough, yet not too much, material. I will have to be the one to find all of the reading tasks, invent topics for art and guide writing essays, etc. . . . ' (Teacher 68) 'Acknowledge all the students adequately.' (Teacher 59)	Implementation	13.7
F3: Integrated lessons require more time from the teacher than carrying out traditional lessons (0.86)	'More time is spent guiding personal project work and [with] assessment. There are also many meetings.' (Teacher 82) 'Planning takes time.' (Teacher 42)	Resource-Time	24.2
F3: Because of a lack of time, implementing integrated education in collaboration with other teachers is difficult (0.46)	'Larger collaboration requires greater personal input outside teaching time, especially at the beginning.' (Teacher 43) 'Scheduling my own teaching with other teachers, teaching groups and issues to be dealt with. Even though there is enthusiasm, good plans are only partly executed because of a lack of time and different schedules.' (Teacher 94)		
	'Courses that could have a lot in common are offered to students in different periods.' (Teacher 30) 'It requires special arrangements from the principal and more resources also for planning.' (Teacher 8)	Administration	25.0
	' . . . one can't execute integration because of the large number of students, and it is impossible to arrange decent sized groups in a manner that allows students into all the courses at the same time. We have even tried to execute an integrated unit with four teachers and four different disciplines, but we did not manage to make the students choose all the required courses at the same time. The current structure should be dismantled for authentic integration to be possible.' (Teacher 64)		
	'Most materials are meant for subject teaching.' (Teacher 43) 'It is difficult to choose the proper materials from all the material out there.' (Teacher 34)	Resource-Other	9.7
	'At the moment, in lower secondary schools people are stuck in their own cubicles teaching their own subjects. Integrated education happens mostly just as talk.' (Teacher 51). 'Students are too conservative and beg for subject boundaries.' (Teacher 12)	Attitude	11.3
	'Small pupils have relatively few skills for working autonomously.' (Teacher 88) 'Basic chemistry must be mastered before teaching can be integrated with other disciplines, such as biology, home economics or physics.' (Teacher 92)	Competence	6.5
F1: Teachers' self-efficacy for ISE	'[All teachers must have . . .] also internalized the method on some level'. (Teacher 38) 'Teacher's knowledge and skills must be sufficiently broad in order to make teaching truly integrated instead of just binding a single lesson to part of a whole unit.' (Teacher 43)		
		Other	7.3
		Total	100

Science teachers did have more to say about two time-related issues. The first issue has to do with always feeling rushed while teaching and not having enough time to teach everything. This includes a notion represented by the factor variable that ISE requires more time from teachers in the classroom. The second time-related issue is that of collaboration, a challenge factor that can partly be seen as an administrative issue.

Administrative challenges are viewed as external by teachers, thus successfully managing them is rarely in the hands of the teachers alone (e.g., curricula and schedule-related issues). In some cases, administrative challenges reportedly emerge because teachers view ISE as something forced on them in a top-down process:

> *'The greatest challenge is the pressure coming from superiors, who dictate that we need to plan integrated study units with a different group each year (the old and already functioning plans cannot be used). These [study units] need to last a certain amount of time, and all subjects must be incorporated within them, even if they do not bring any practical benefits. However, nothing can be taken out of the old syllabus, nor can the hours spent on planning be taken away from somewhere else. Thus, I as a teacher will have to do more work and compress the actual content into a smaller time frame.'* (Teacher 97)

The competence category as a challenge included statements relating either to teachers' professional competence or to students' abilities and skills. The former statements are linked to factor 1) self-efficacy for ISE. In addition, we discovered a negative correlation (−0.35) between self-efficacy and challenge factors (see Table A3 in Appendix A), suggesting that teachers with lower self-efficacy for ISE perceive integration as somewhat more challenging.

4.2. Teachers' Self-Efficacy

Teachers' self-efficacy for ISE was emphasised as a key factor explaining most (23.04%) of the total variance in teachers' perceptions of ISE. It consisted of seven items with factor loadings ranging from −0.60 to −0.86 (see Table A2 in Appendix A). All items referred to high self-efficacy statements, such as '*I possess a sufficient amount of knowledge to implement integrated education*' (−0.86), and were negatively loaded, thus indicating that the latent factor is actually opposite: low self-efficacy. On average, teachers neither agreed nor disagreed with the factor statements (mean 3.20), however their answers varied greatly from '*I strongly disagree*' to '*I strongly agree*'.

In addition, few self-efficacy related challenges emerged from the content analysis, indicating that teachers tend to regard the implementing of ISE as possible only with a certain set of skills, knowledge and professional competence:

> *'[All teachers must have . . .] also internalised the method on some level.'*(Teacher 38)

> *'Teachers' knowledge and skills must be sufficiently broad in order to make teaching truly integrated instead of just binding a single lesson to part of a whole unit.'* (Teacher 43)

Cross tabulation revealed statistically significant differences (p = 0.028, Fisher's Exact Test) between primary and secondary school teachers with regard to their self-efficacy. Primary school teachers showed more confidence in their own abilities at executing ISE lessons and their understanding of integration (46.5% agreed or strongly agreed with the factor statements and only 10.7% disagreed). Secondary school teachers demonstrated more variance in their answers and especially upper secondary teachers expressed less confidence in their competence and more need for support, with 28.6% disagreeing or strongly disagreeing with the factor statements.

Furthermore, teachers who reportedly engage in integrated activities seldom or never expressed lower self-efficacy beliefs (p = 0.001, Fisher's Exact Test) and perceived ISE as more challenging (p = 0.039, Fisher's Exact Test). Teachers with less experience in interdisciplinary collaboration agreed more strongly with statements on the challenges of ISE (p = 0.025, Fisher's Exact Test) and tended to have lower self-efficacy beliefs (p = 0.053, Fisher's Exact Test). The latter difference, however interesting, is not statistically significant.

5. Discussion and Conclusions

In this study, the focus was twofold: (1) to understand how teachers perceive ISE and (2) to assess if science teachers' perceptions of and experiences with integrated education influence their views on self-efficacy in relation to ISE. We used EFA as a starting point to reveal latent factors explaining teachers' perceptions of ISE, and further elaborated on these factors via the content analysis and by comparing them to the experiences teachers reportedly have had with ISE (see Figure 1). Self-efficacy emerged as a key factor explaining teachers' perceptions of and their lack of confidence in implementing ISE as well as their need for support.

The majority of the science teachers in the study had a general understanding of integrated education, though their definitions of it varied. The variance was expected, as there is no consensus on a single definition even among researchers [22]. For the most part, the teachers' definitions emphasised (1) collaboration between subjects, which we categorised either as multidisciplinary or as interdisciplinary, and (2) the importance of examining the complexity of issues as a comprehensive whole and via a phenomenon-based approach. The latter may partly be explained by the approach of the Finnish National Core Curriculum [15] to integrated education. Teachers emphasised the former—collaboration—as vital for the implementation of ISE and felt that it constitutes a time- and administration-related challenge, a finding corroborated by earlier research [5].

The challenges that teachers associated with ISE, e.g., time constraints, administrative issues and laborious implementation, are well in line with earlier findings [5,7,19]. Interestingly, the issue of implementation constraints did not only come up in the question about the challenges of ISE, they emerged as a separate factor and were present in answers on the benefits of and proper way to define ISE. The plethora of challenges reported by teachers can partly be explained by the fact that ISE is still a novelty for Finnish science teachers, a conclusion supported by the number of "I don't know" responses and insecurity showed by teachers when defining integration. Furthermore, it may indicate teachers' frustration with how the educational reform is being executed and with the top-down mandate (see [13]) to use integrated approaches, as Finnish teachers are accustomed to being pedagogically autonomous.

Despite the challenges, these results also indicate that the majority of the science teachers perceive ISE as being relevant for their subject teaching and are willing to implement it more often. Teachers' perceptions of the relevance of ISE are aligned with the three dimensions (personal, vocational, societal) suggested by Stuckey et al. [60], although the issue of personal relevance was mentioned for both students and teachers themselves. Teachers emphasised three sources of relevance above all others: integrity of knowledge, motivation and meaningfulness of ISE. This perception of ISE as relevant should influence how it is implemented in classrooms [5,27,47]. This finding is corroborated by the evidence from the 26 teachers who, contrary to the other teachers in the study, mentioned mastery of the subject content as an essential aim of ISE. They stated that integration is less relevant and less useful for science education and expressed less of an eagerness to adopt integrated approaches in their teaching. However, even the majority of teachers who perceived ISE as relevant noted that they only implement it on rare occasions and in an irregular manner, with few exceptions. There are at least two possible explanations for this contradiction between willingness to implement ISE and actual practice. First, the perceived obstacles can affect teachers' willingness to implement it, especially if the teacher has lower self-efficacy in relation to ISE [5,49]. Second, conflicting educational beliefs and epistemological beliefs may constrain teachers from implementing even positively valued practices [29,48,61].

The results indicate that especially teachers' experiences with integrated activities and interdisciplinary collaboration correlate with their views of ISE and their challenges and self-efficacy beliefs in relation to ISE. This was evident when studying the perceptions of primary and secondary school teachers. Primary school teachers displayed higher self-efficacy for ISE and a more cohesive understanding of integration, and they had more experience with integrated practices and collaboration than did secondary school teachers.

This difference may be explained by differences in the ways of organising education and the curriculum [5,7], as teachers at all levels quite often reported that they must deal with administration-related challenges. Contradictory findings exist, which indicate that secondary school teachers may have higher self-efficacy for science education [62]. However, as self-efficacy beliefs are context related [30], it follows that teachers' self-efficacy for science education and for ISE are separate beliefs.

In conclusion, science teachers reported having little experience with integrated practices and collegial collaboration. It cannot be deduced from these results whether it is a lack of experience that affects teachers' challenge-centred perceptions and their lack of self-efficacy for ISE, or vice versa. Bandura [30] observed that mastery experiences serve as a primary source of self-efficacy, while at the same time there is evidence that teachers with lower self-efficacy are less prone to try new practices [63].

These results cannot be generalised and might overtly present the opinions of teachers who are actively following online science teacher forums. Nevertheless, we feel that the findings are valuable as they (1) paint a picture of teachers' perceptions and self-efficacy beliefs on the eve of a curriculum change that emphasises integrated approaches and (2) add to our understanding of self-efficacy in the context of ISE.

6. Implications

Similar reforms to those made in Finland are being made or have been made in many countries. Implementing ISE is a novelty to Finnish teachers and presents them with multiple barriers to overcome. These findings highlight self-efficacy as a key factor explaining science teachers' perceptions of and their lack of confidence in implementing ISE in such a situation, as well as their need for support. Furthermore, teachers' prior experiences with integrated approaches correlated with their views on ISE and self-efficacy in relation to ISE.

Assisting teachers with successful implementation and offering training opportunities to carry out integrated activities and interdisciplinary collaboration can positively affect teachers' perceptions and self-efficacy in relation to ISE. This can influence teachers' willingness to engage and implement ISE in future [5]. Teachers need feasible models to integrate ISE with classroom practices that focus on integrated activities and collaboration, while at the same time being relevant for subject teaching. Recent efforts towards this have been made; for example, Gardner and Tillotson [64] explored this with a focus on the collective use of space and time as major component of an integrated STEM model. Another example of a pedagogical model is Learn STEM [65] which has been designed in collaboration with researchers and secondary schools in six European countries. Nevertheless, there is still a lot of uncertainty around the implementation possibilities of STEM [17].

Teachers' beliefs are conceived as immutable, incontrovertible and persistent over time [26,29], and the influence of these beliefs can be traced back to when teachers were students themselves [66]. Therefore, ISE reform may be integrated with classroom practices more sufficiently if ISE is taken into consideration already during pre-service teacher training. Some efforts towards this have been made; for example, in their case study, Kousa et al. [67] found out that an interdisciplinary school–industry collaboration course can be an effective way to implement STSE issues into pre-service teaching and significantly raise pre-service teachers' confidence and readiness to teach STSE issues.

Additionally, a collaborative primary–secondary school teacher training programme could be an opportunity to support teachers in future ISE teaching since primary school teachers seem to have higher self-efficacy and more experience with integrative approaches and secondary school teachers have more confidence in teaching science as a subject. However, more research is needed to clarify the feasible models for introducing ISE into pre-service and in-service teacher training and the impact of different teacher training programmes on teachers' beliefs about ISE.

Integrated education remains a desired teaching practice, and teachers need to have a strong sense of their own capabilities in order to overcome the identified challenges. These findings indicate that on the eve of a curriculum change emphasising integration, Finnish science teachers expressed a varied understanding of ISE and their self-efficacy was as a key factor explaining their lack of confidence in implementing ISE, as well as their need for support. Therefore, policymakers and teacher trainers advocating ISE must not ignore teachers' perceptions and self-efficacy beliefs or else integration will remain insufficiently implemented in science education.

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Appendix A

Table A1. Science teachers' experience with teaching, integrated practices and collaborating with colleagues.

Science Teachers' Teaching Experience							
	Over 10 years	6–10 years	3–5 years	1–2 years	Less than a year	Total	
Teaching experience	72	11	9	2	1	95	
Teaching experience (%)	75.8	11.6	9.5	2.1	1.0	100.0	
Science Teachers' Experience in Integrated Education							
	Never	1–2 times per year	3–5 times per year	Over 5 times per year	1–2 times per month	Over 2 times per month	Total
Integrated practices							
Parallel subjects	19	37	9	10	8	10	93
Periodic subjects	16	16	17	17	5	18	89
Integrated activities	6	43	22	15	3	4	93
Total	41	96	48	42	16	32	275
Total (%)	14.9	34.9	17.5	15.3	5.8	11.6	100.0
Collaboration with Colleagues							
Within the subject	16	25	19	13	6	14	93
Interdisciplinary	26	38	14	8	3	3	92
Total	42	63	33	21	9	17	185
Total (%)	22.7	34.0	17.8	11.4	4.9	9.2	100.0

Table A2. Factor loadings and extracted communalities of exploratory factor analysis regarding science teachers' perceptions of integrated education (IE). All loadings < 0.2 were omitted.

Variables	Factor				Communalities
	1	2	3	4	
1. Factor: Self-efficacy					
I possess a sufficient amount of knowledge to implement IE.	−0.86				0.71
I don't need any support for implementing IE.	−0.82			−0.20	0.64
I can plan and execute integrative learning modules.	−0.77				0.66
I have adequate skills to implement IE.	−0.72			−0.27	0.60
I don't need more integrative teaching material for implementing IE.	−0.66				0.40
Taking integrative instructions into account in my own teaching is easy for me.	−0.62	0.29			0.60
I know enough about other subjects to implement IE.	−0.60	−0.22			0.44
2. Factor: Relevance					
I would like to use more integrated approaches in my teaching.	0.23	0.86			0.65
I think it is important to implement integration within my own teaching.		0.82			0.73
I think IE is a suitable method to teach the subjects that I am teaching.	−0.25	0.69			0.59
IE helps students to understand the interconnected nature of issues better than traditional education.		0.68			0.57
With IE, one can achieve better learning outcomes than with traditional education.		0.61	−0.25		0.60
3. Factor: Challenges					
Integrated lessons require more time from the teacher than carrying out traditional lessons.			0.86		0.66
Implementing integrated education is more laborious than traditional education.			0.85		0.66
Implementing integrated education requires cutting down on subject content.			0.50		0.40
Because of a lack of time, implementing integrated education in collaboration with other teachers is difficult.			0.46		0.33
4. Factor: Multifaceted nature of integration					
A student-centred approach is essential in IE.				0.68	0.42
IE should be linked to students' daily lives and to society.				0.57	0.36
In IE, one must apply the skills and knowledge learned within the context of everyday life.			0.30	0.55	0.44
IE requires collaboration between subjects.				0.46	0.25
In IE, it is essential to examine the complexity of a phenomenon comprehensively.				0.45	0.29
Total variance explained by the factors (squared loadings. %)					52.46
1. Factor: Self-efficacy					23.04
2. Factor: Relevance (of IE)					16.43
3. Factor: Challenges (of IE)					7.94
4. Factor: Multifaceted Integration					5.06

Extraction Method: Principal Axis Factoring with a fixed number of factors.
Rotation Method: Promax with Kaiser Normalisation. Rotation converged in 5 iterations.

Table A3. Descriptive statistics for the four factors relating to science teachers' conceptions of integrated education (n = 89) and the factor correlation matrix (the negative factor loadings of F1 have been taken into account in the factor correlations).

	N of Items	Mean	SD	Variance	Skewness	Kurtosis	Cronbach's Alpha	Factor Correlation Matrix F1	F2	F3	F4
F1. Self-efficacy	7	3.20	0.84	0.71	0.07	−0.45	0.874	1.00			
F2. Relevance	5	3.92	0.81	0.66	−1.00	0.77	0.858	0.12	1.00		
F3. Challenges	4	3.69	0.82	0.67	−0.63	0.30	0.765	−0.35	−0.32	1.00	
F4. Multifaceted Integration	5	4.17	0.58	0.33	−0.58	−0.42	0.688	0.11	0.44	−0.13	1.00

Extraction Method: Principal Axis Factoring.
Rotation Method: Promax with Kaiser Normalisation.

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